LIGHT COUPLING IN QUANTUM WELL INFRARED PHOTODETECTORS

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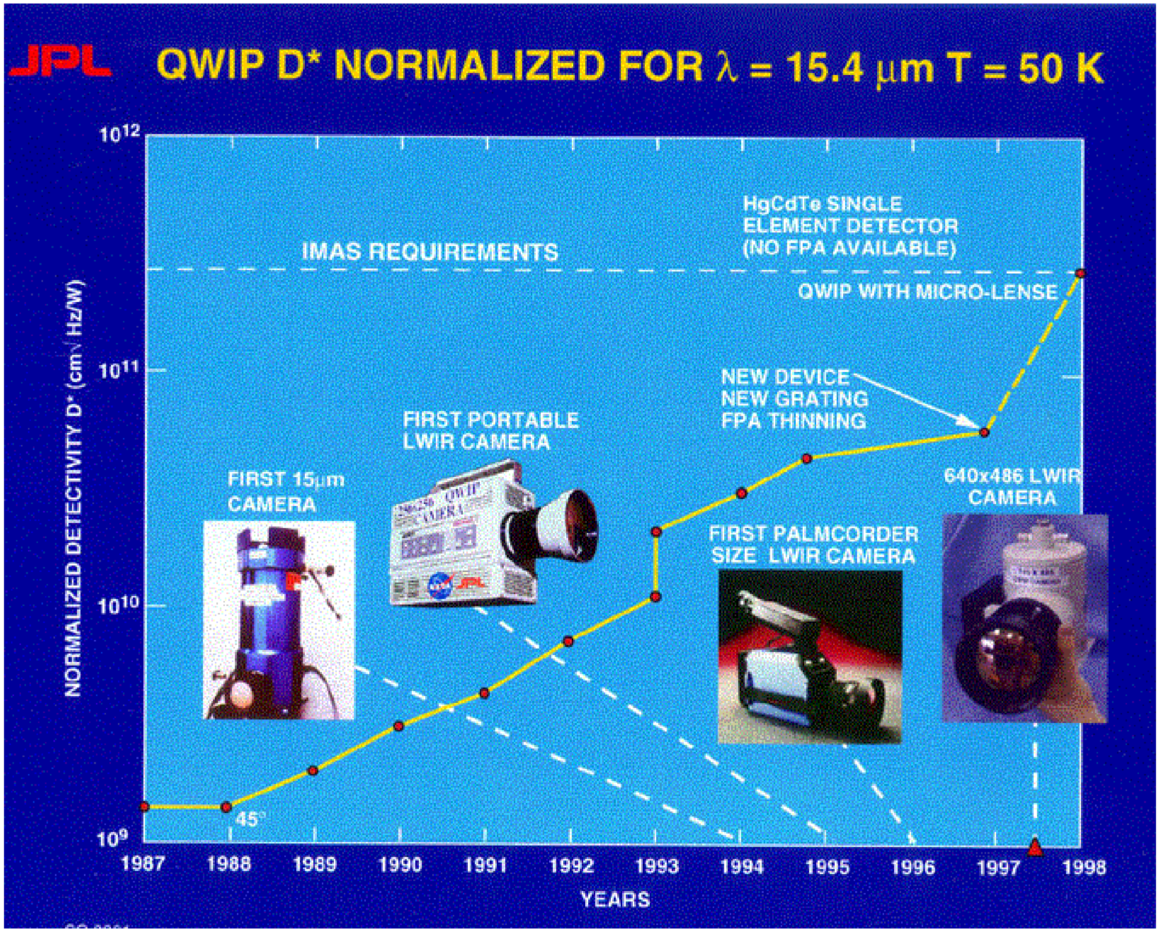
Overview

Quantum Well Infrared Photodetectors: roadmap

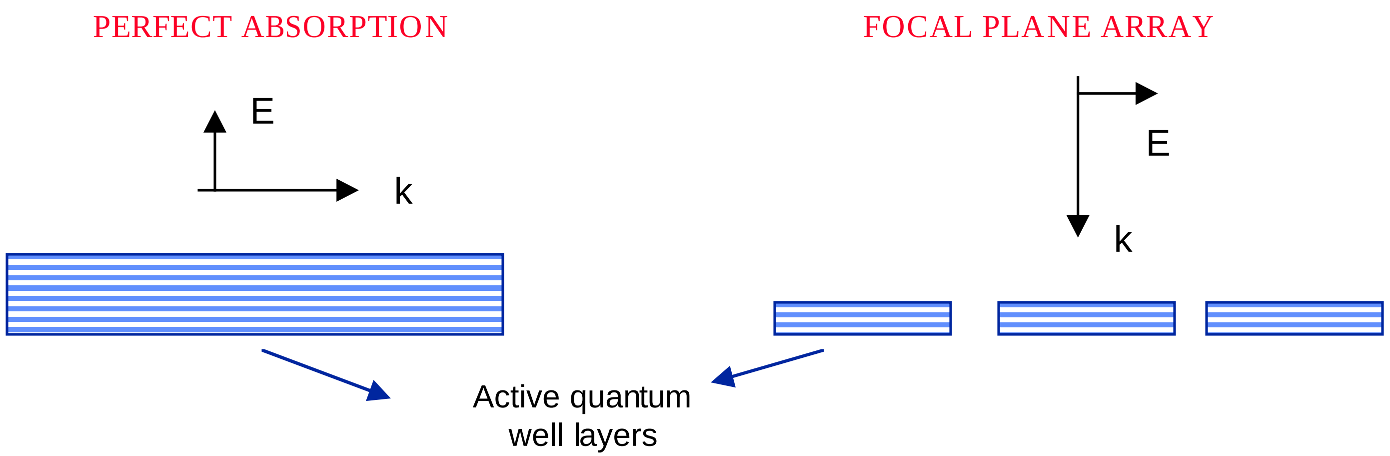


Sarath Gunapala et al., JPL

Light Coupling and Absorption

Energy Absorption in QWIPs

- Electric field must be perpendicular to quantum well layers
  - » *But …*
- Focal plane arrays require direction of propagation to be perpendicular to quantum well layers

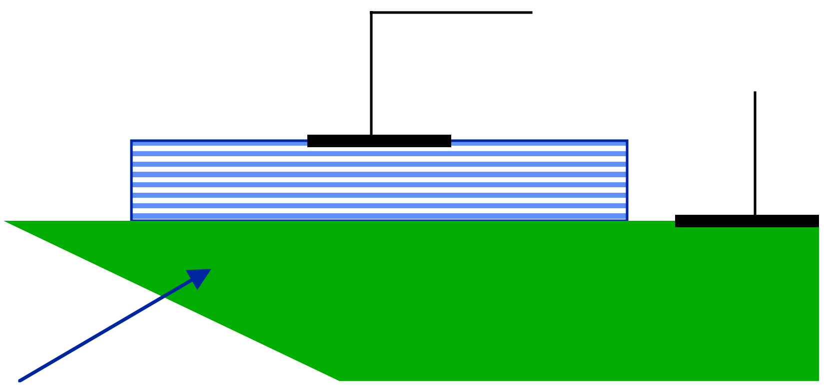


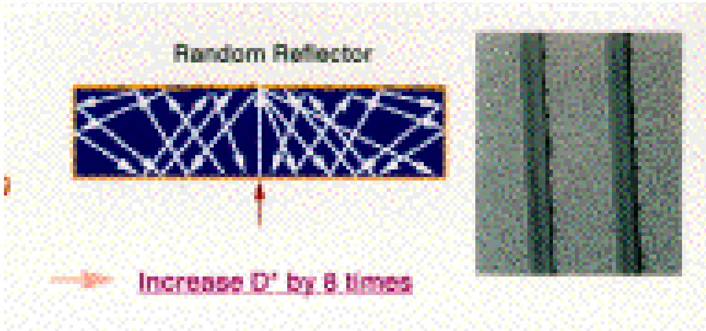
LIGHT COUPLING IN QWIPs

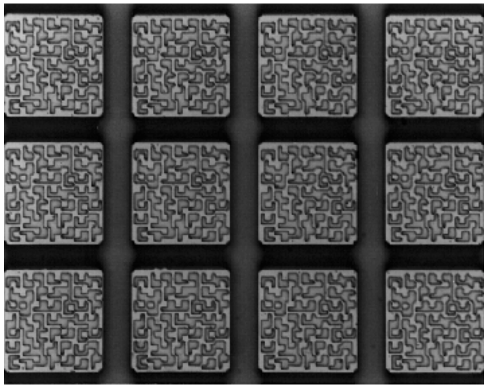
Historically …

Random surface scatterer

Standard 45 degree edge detector





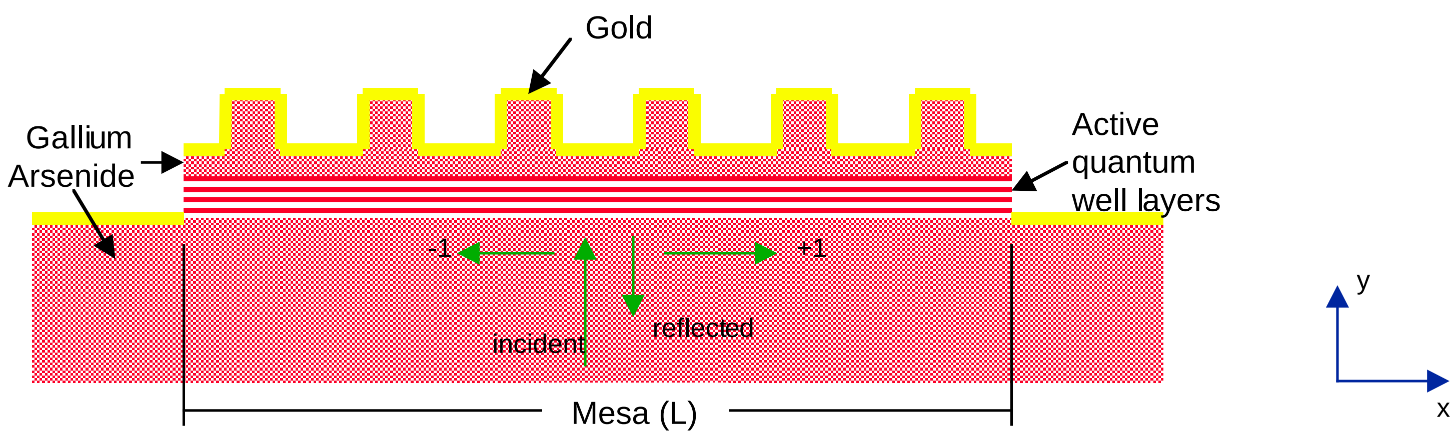


Expanded corner of 128x128 QWIP focal plane array with 38x38 micron squared pixels.

Grating Structures

Grating structures built on mesa to create $\pm$Floquet harmonics

Dark current produced in active quantum well layers



Define Figure of Merit for light coupling; account for dark current by area of region

$$\textit{figure of merit} = \frac{\iint |E_y(x,y)|^2 \, dxdy}{\sqrt{L}}; \quad \text{integral over active region}$$

LIGHT COUPLING IN QWIPs

Coupled Finite Element - Integral Equation Analysis

Apply finite element analysis to each pixel of focal plane array

- Model geometry using finite element mesh
- Truncate mesh using integral equation around boundary
- Apply two-dimensional analysis initially to plane through cross-section of grating

Perform interpolation and differentiation to calculate electric fields

- H-polarization of interest (H in/out of plane; TEy in our geometry)
- Calculate figure of merit over quantum well active region

Examine grating geometry, mesa size and effects of microlens

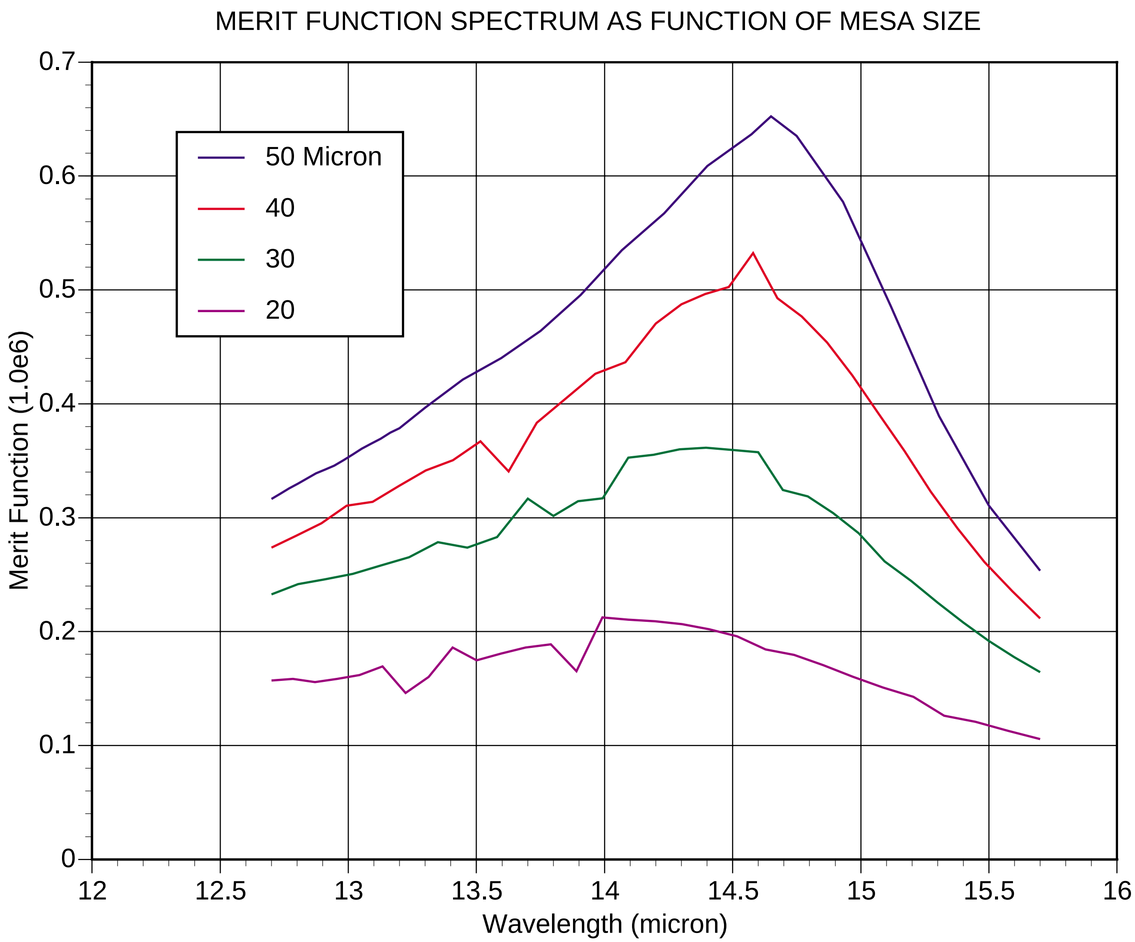
1) For optimum grating, compare figure of merit vs. mesa size

2) Add microlens to collect 50µ aperture of energy and focus on 20µ mesa

3) Examine model for incident field from microlens on mesa structure

LIGHT COUPLING IN QWIPs

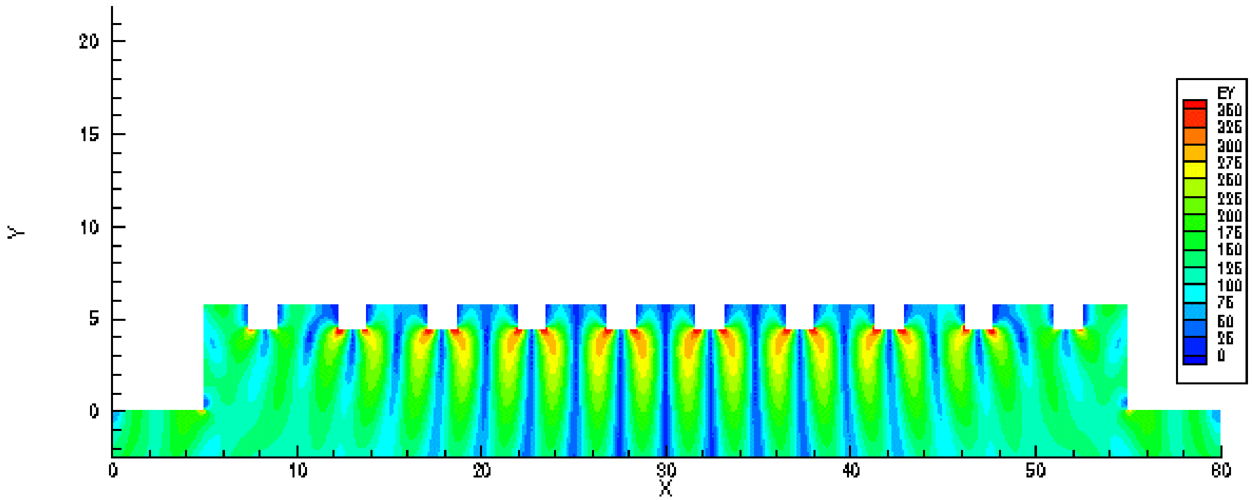
Results for Varying Mesa Width

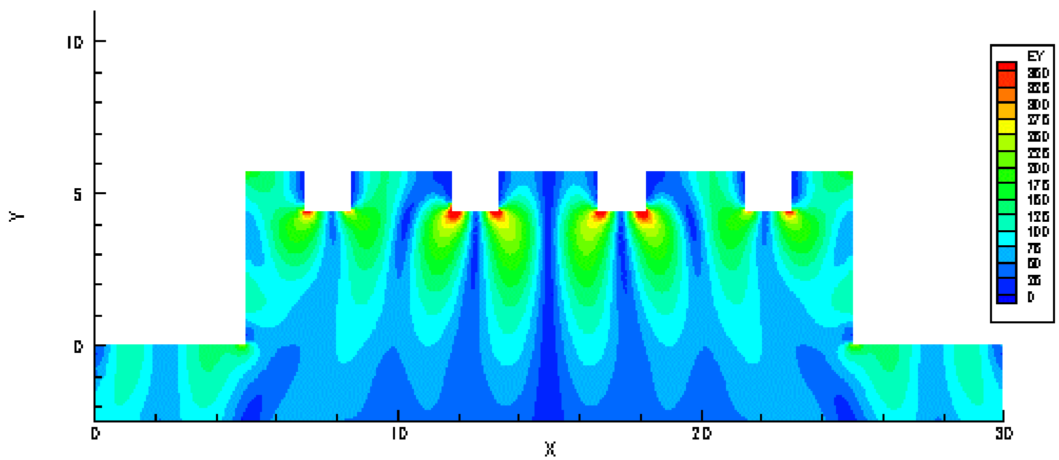


LIGHT COUPLING IN QWIPs

50 and 20 Micron Mesa Structures

Electric Field component y; 14.65µm



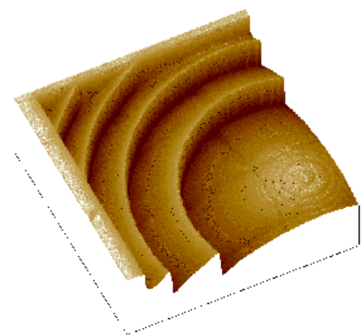


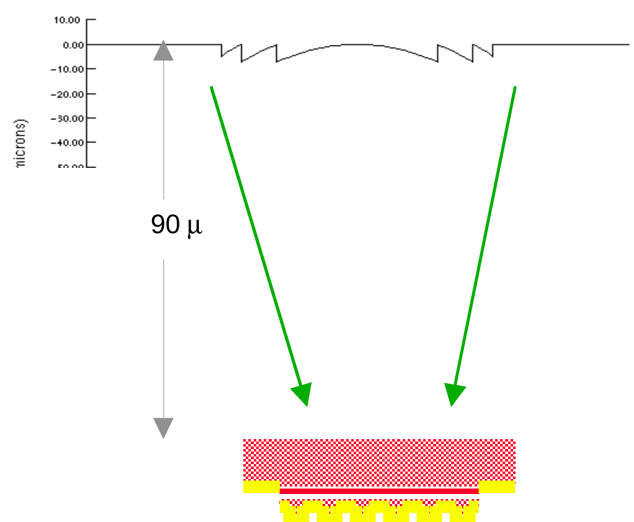
LIGHT COUPLING IN QWIPs

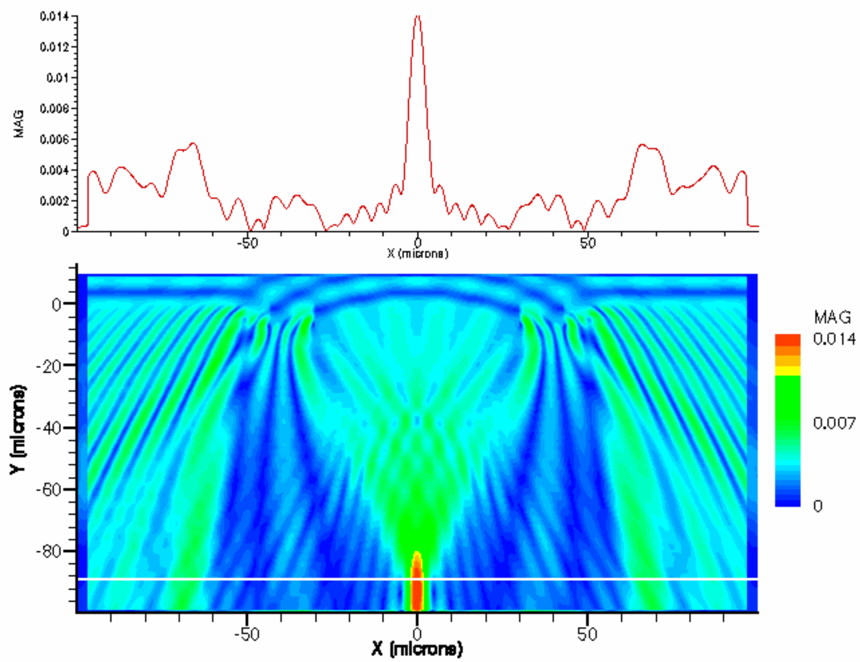
Can a Microlens Improve Performance

- Maintain collecting area and decrease mesa size

  reduce dark current





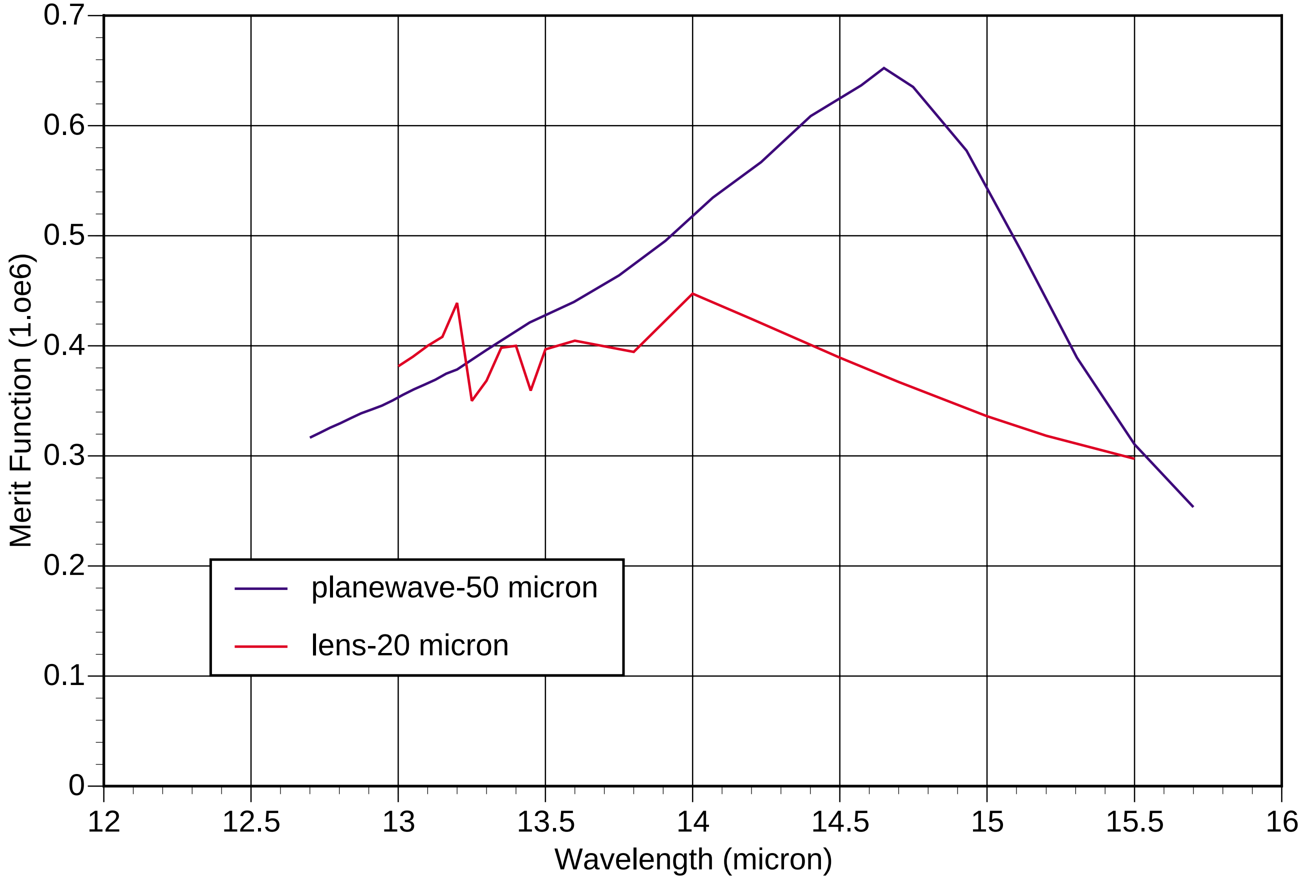


Simulation by Dr. Daniel S. Katz, JPL

LIGHT COUPLING IN QWIPs

Effect of Lens and Smaller Mesa

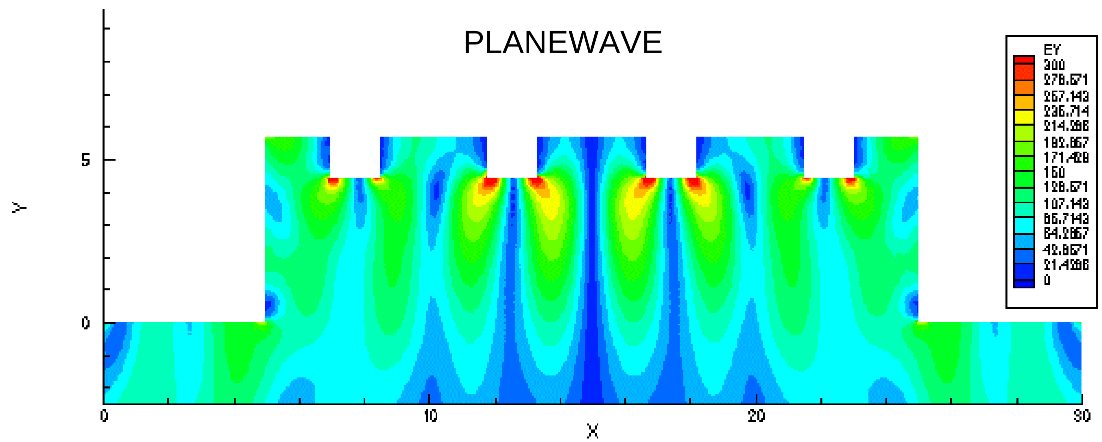
COMPARISON OF LENS AND 20 MICRON MESA TO 50 MICRON MESA

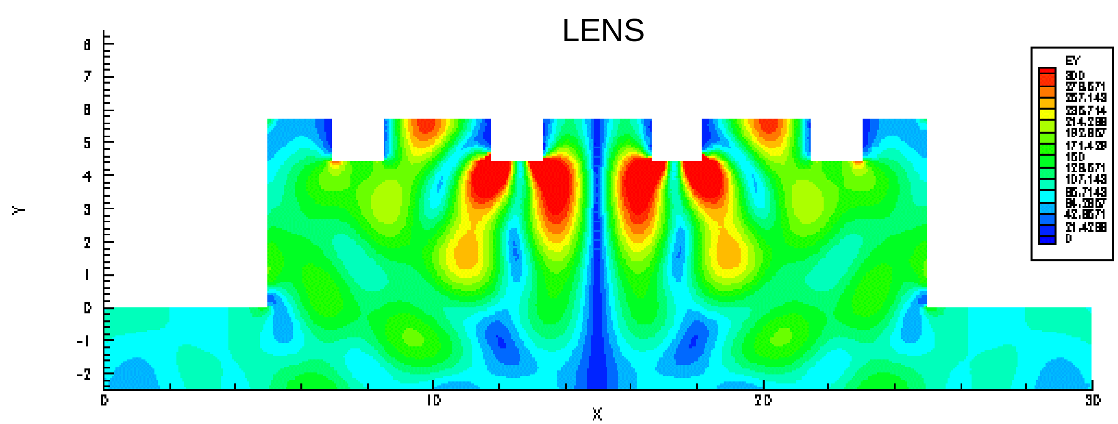


LIGHT COUPLING IN QWIPs

Planewave and Lens Incidence on 20µ Mesa

Electric Field component y; 14.0µm

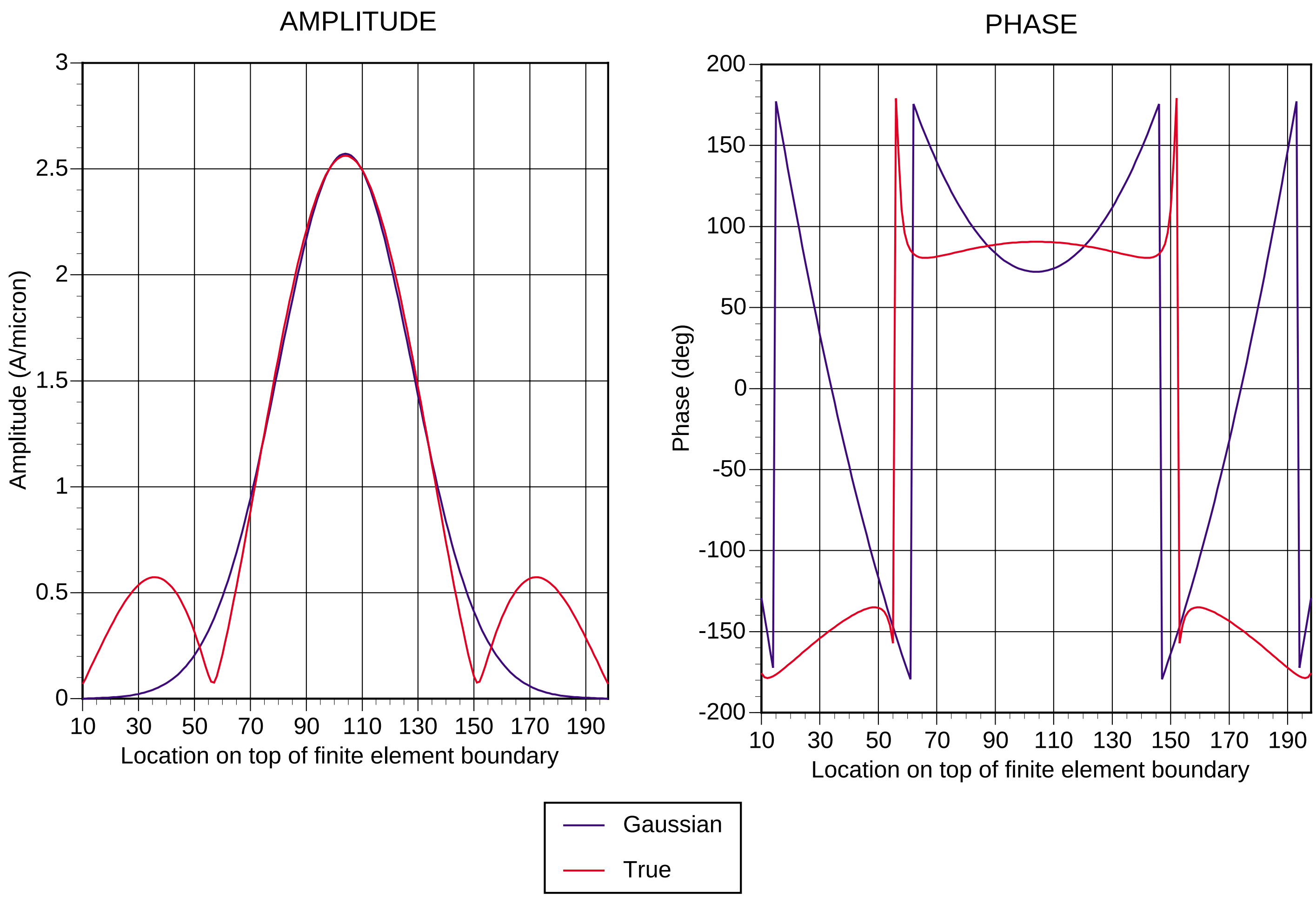




LIGHT COUPLING IN QWIPs

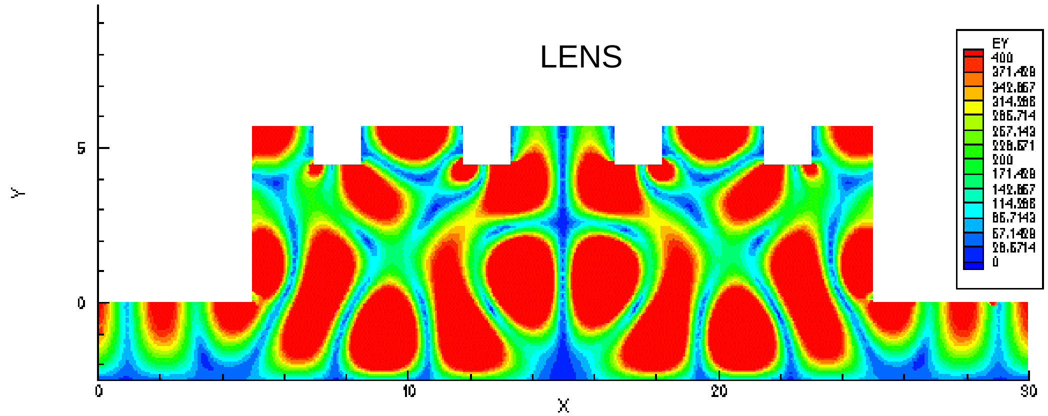
Modeling Field Incident on Mesa Structure

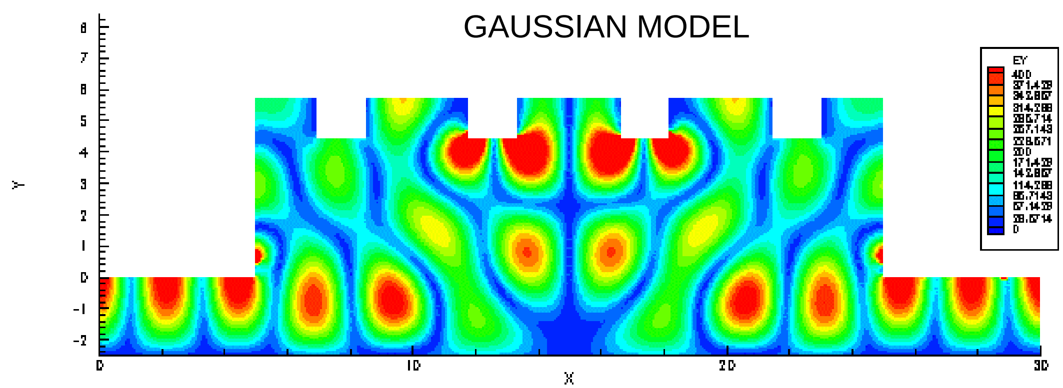
Gaussian Model vs. Plane-wave Expansion of Lens field; 13.0 μm



True Lens Field vs. Gaussian Model

Electric Field component y; 13.0 µm





Conclusions

As mesa size decreases, finite grating does not produce first harmonics appropriately

- *Savings in dark current are offset by decrease in grating performance*
- *Grating (periodic surface) does not act as infinite grating*

Use of microlens to collect more energy (over 50µm aperture) does not compensate smaller mesa and finite grating size

- *Microlens will dump more energy into mesa structure, but cannot compensate smaller grating*

Necessary to model microlens accurately when used as incident field on finite element simulation

- *Approximate gaussian model does not model phase properly; especially important for periodic grating structure*